

Preliminary Results of ANAIS-25 at the Canfranc Underground Laboratory

María Luisa Sarsa

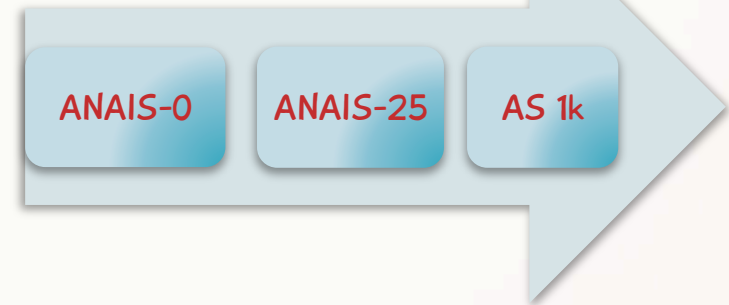


(On behalf of the ANAIS Experiment Research Team)



Outline

Searching for radiopure
NaT(l) powder



**The ANAIS
Experiment**

**NaI(Tl)
crystal**

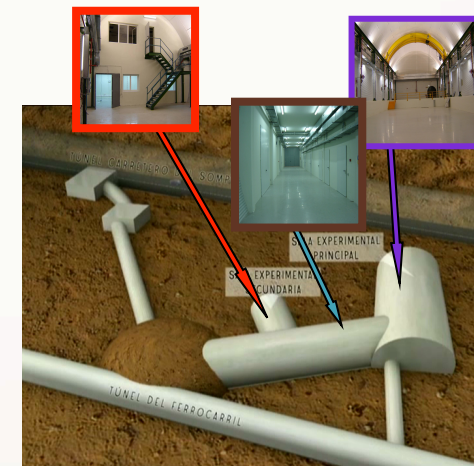
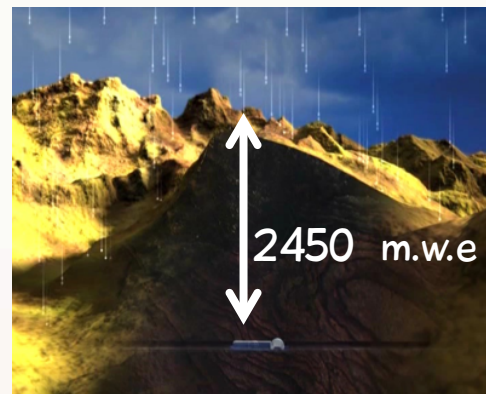
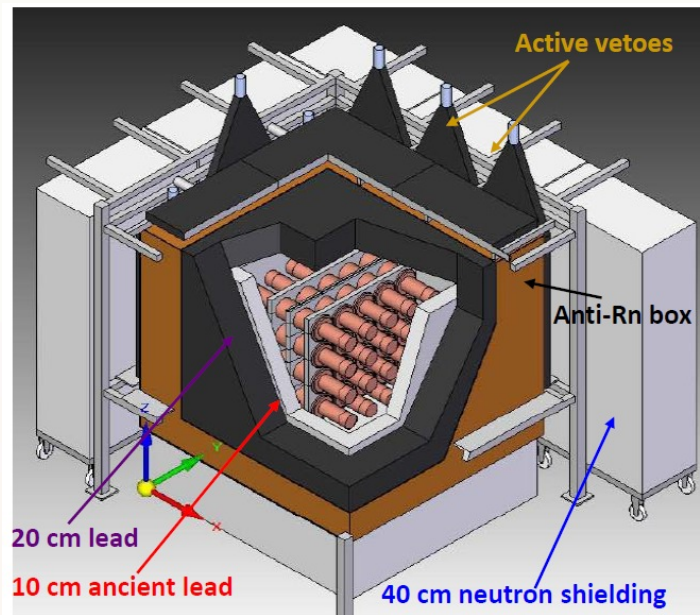
**PMT
choice**

**Other
results**

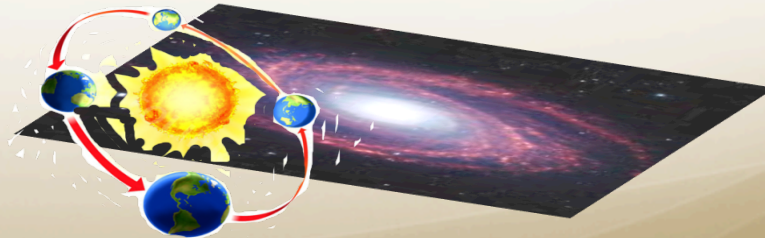
Slow scintillation
in NaI(Tl) crystals

The ANAIS Experiment

250 kg of ultrapure NaI(Tl)
detectors at the Canfranc
Underground Laboratory (LSC)



Goal: study the annual modulation in the dark matter signal

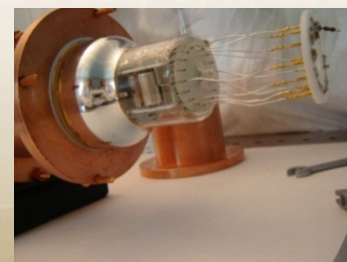


SAME TARGET AND TECHNIQUE AS DAMA/LIBRA

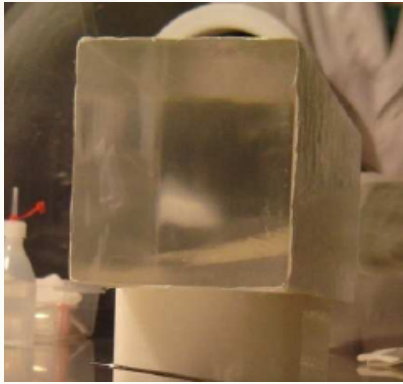
The ANAIS Experiment

Long effort in R+D at the University of Zaragoza through the operation of several prototypes

- HPGe radiopurity test bench for material selection: specially NaI powder from different providers
- PMT Testing
- Light collection efficiency study
- Background understanding / simulations
- Optimization of data analysis and readout

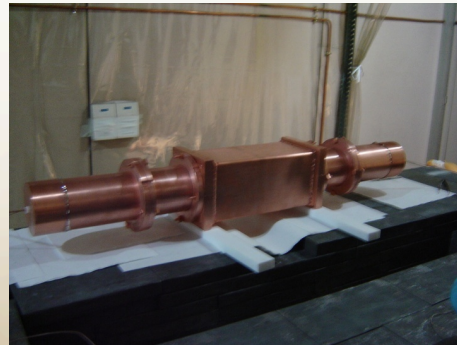
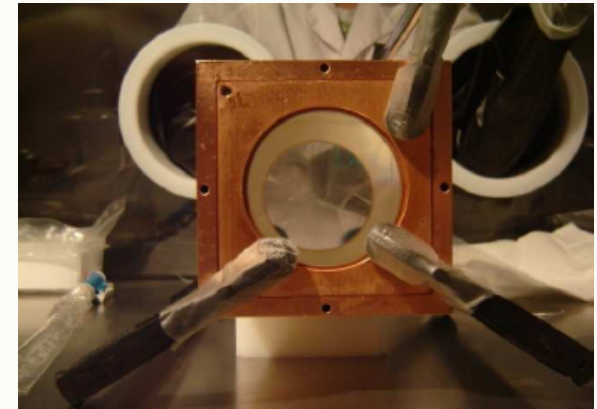


AN AIS-0 Prototype



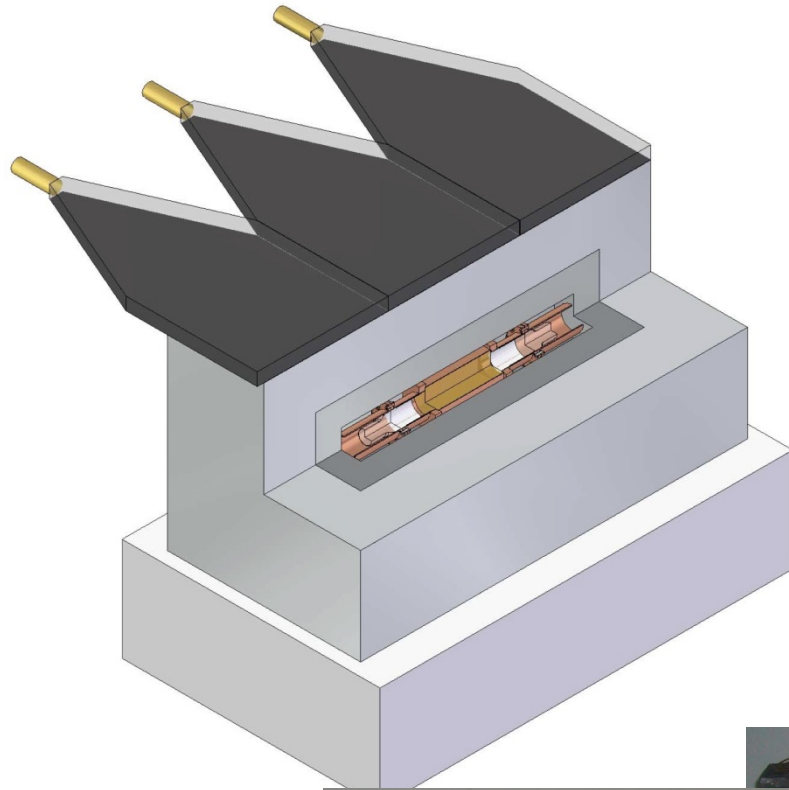
AN AIS-0 consists of a 9,6 kg NaI(Tl)
crystal made by Saint Gobain
4"x4"x10"

Encapsulated at the UZ using ETP Copper
Choice of using LG and test different
PMTs

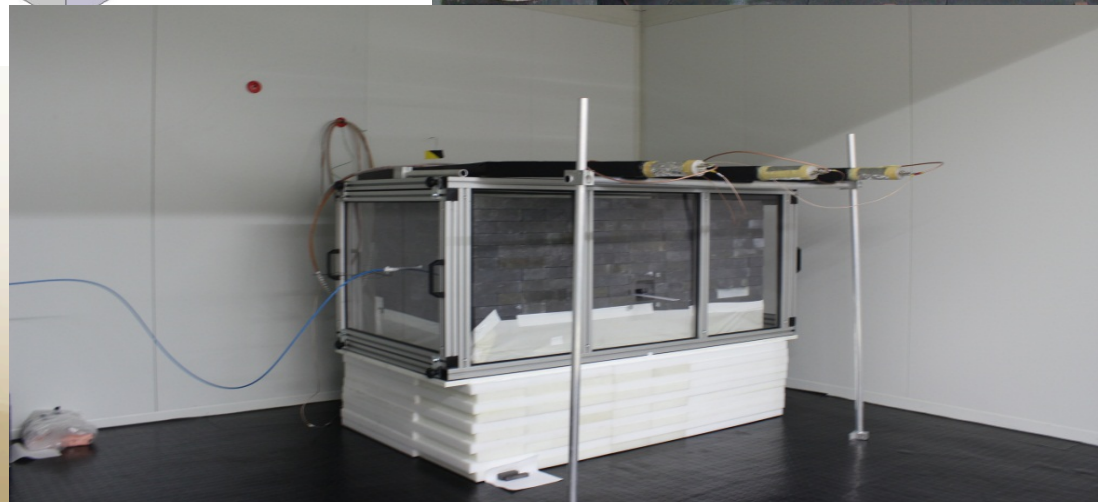


2009-2012

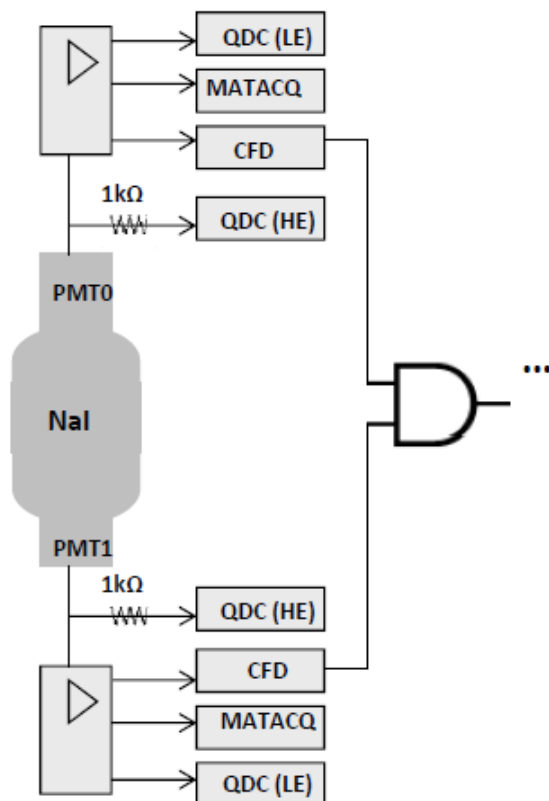
AN AIS-0 shielding



- 10 cm archaeological lead
- 20 cm low activity lead
- Tightly closed box kept with boil-off nitrogen overpressure
- Three plastic scintillators as muon vetoes



ANAIIS-0 DATA READOUT



- Bus VME/NIM
- Two signal lines/module symmetrical
- Trigger: logical AND (200ns coincidence window)
- Energy estimator: QDC in three different dynamic ranges
- Pulse shape: MATAcq card (2GS/s, 12 bit vertical resolution, 1,25 μ s window)

- **SCALABLE FOR ANAIS**
- **TESTED WITH TWO MODULES**
- **FULLY COMMISSIONED**

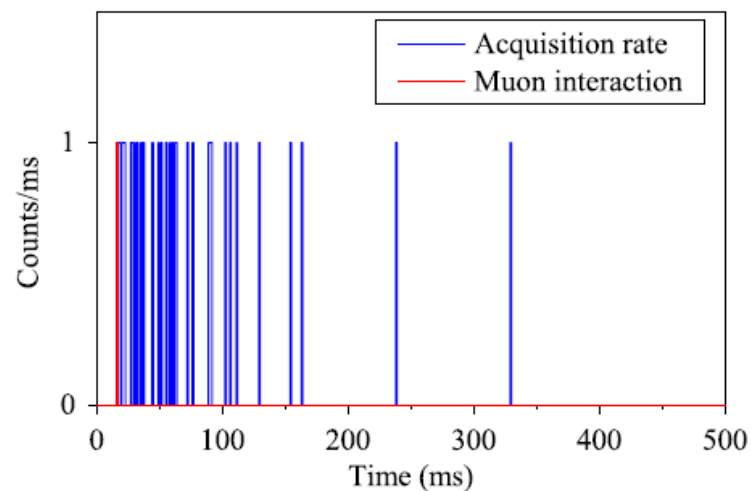
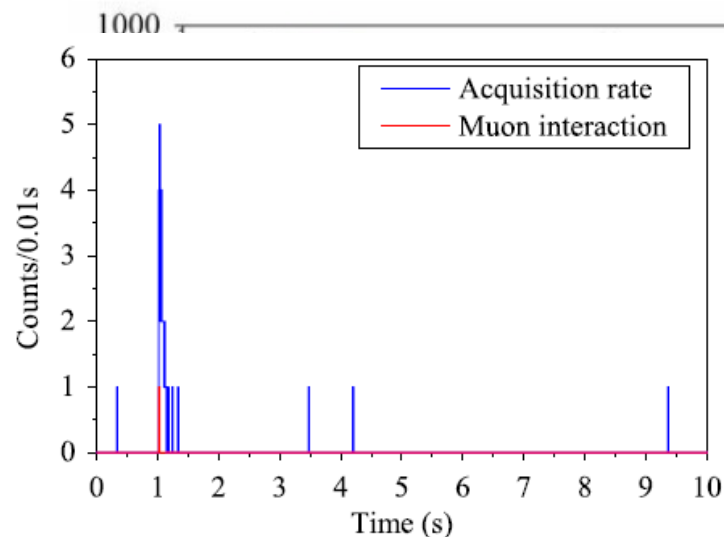
ANAIS-0 Relevant Results

MUON RELATED EVENTS have been identified and removed from data

1. Events coincident with a muon in the plastic scintillators
2. Events 0.5 s after a very high energy deposition (muons but not only...)



Muons produce scintillation in LG, contributing below 100 keV



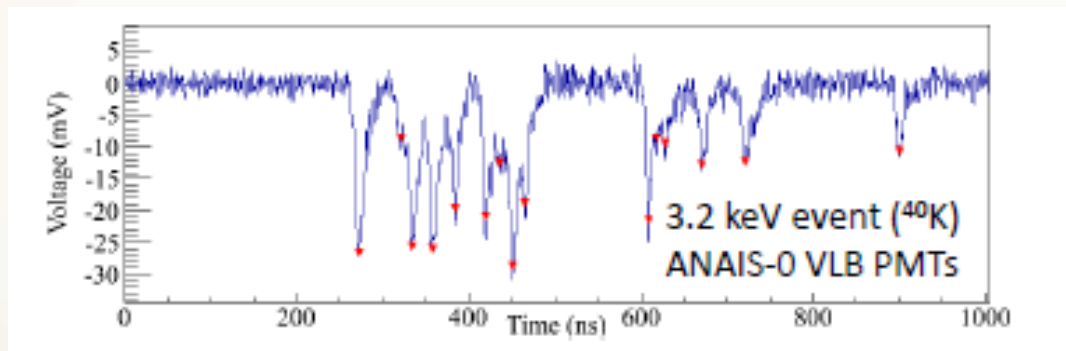
rate after a
ν scintillation

ANAIS-0 Relevant Results

We want to select real bulk NaI scintillation events

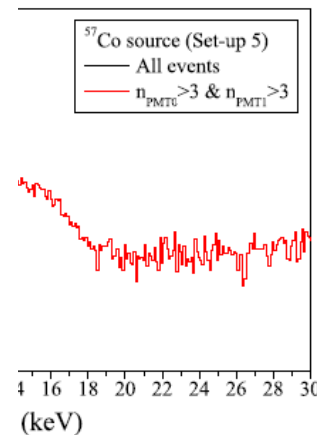
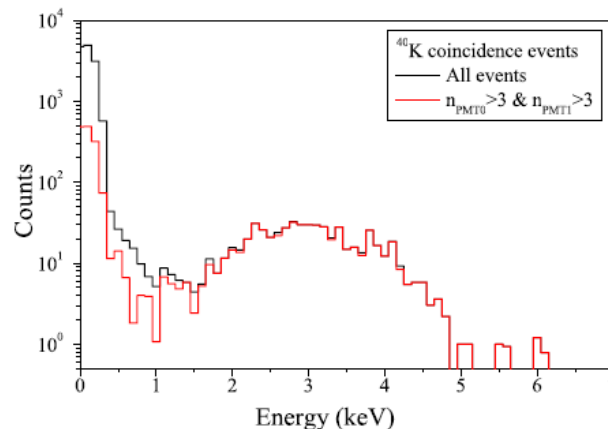
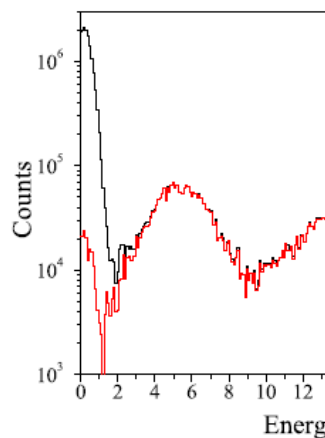
CUTS have been developed for:

- Rejection of PMT origin events



We count the total number of peaks (ph.e.) in every low energy event

$n > 3$ for each PMT

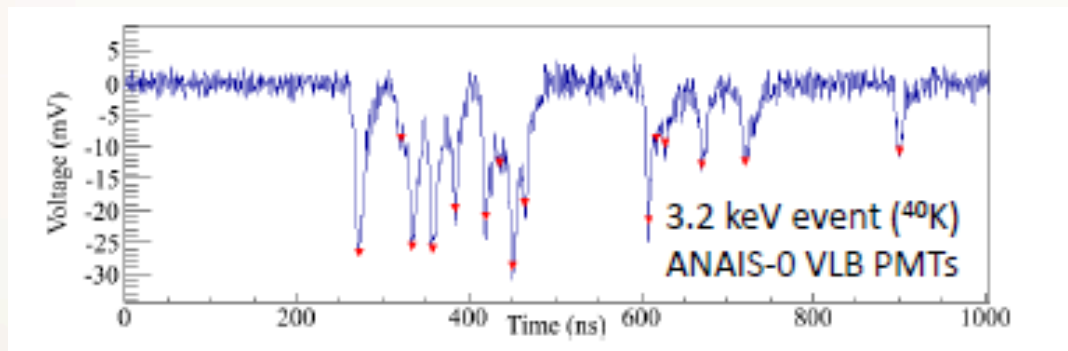


ANAIS-0 Relevant Results

We want to select real bulk NaI scintillation events

CUTS have been developed for:

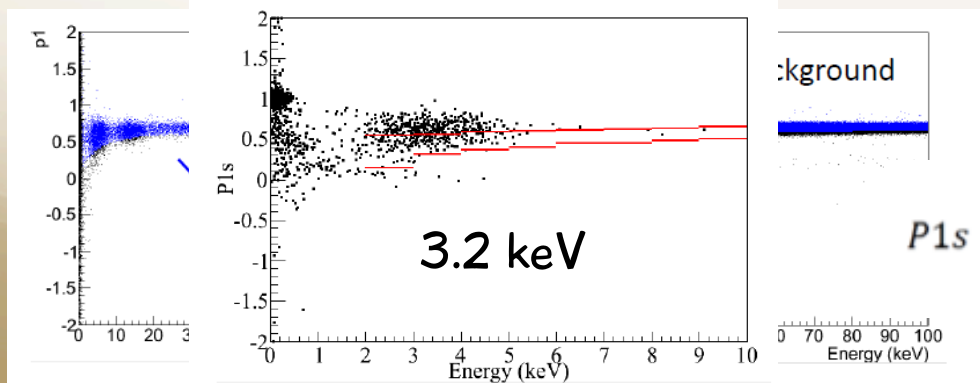
- Rejection of PMT origin events



We count the total number of peaks (ph.e.) in every low energy event

$n > 3$ for each PMT

- Rejection of anomalous fast events

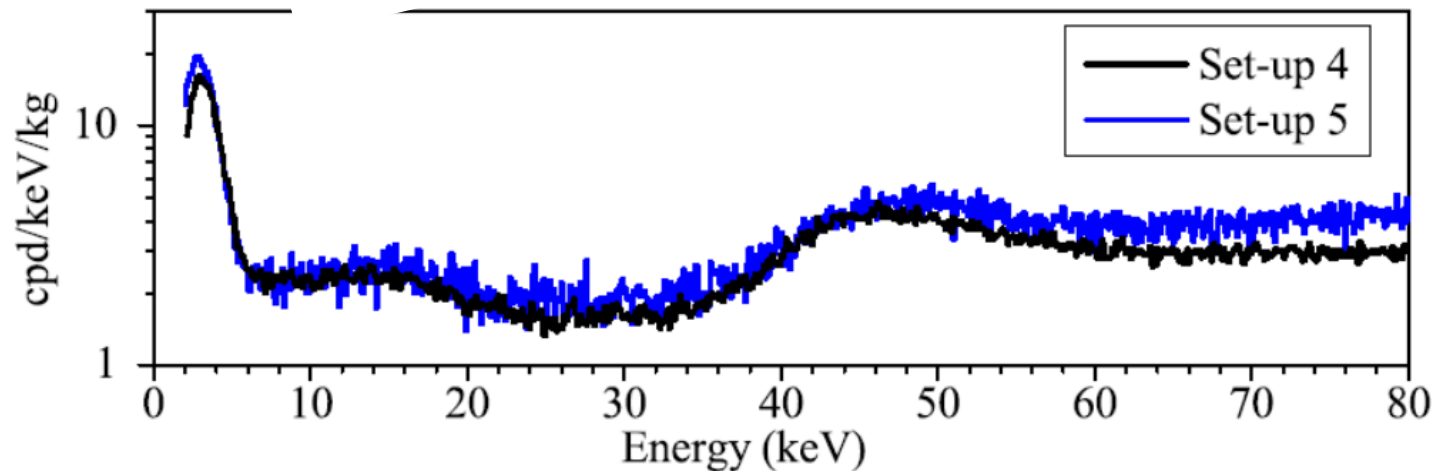


$$P1s = \frac{\text{area1}(100 - 600 \text{ ns}) + \text{area2}(100 - 600 \text{ ns})}{\text{area1}(0 - 600 \text{ ns}) + \text{area2}(0 - 600 \text{ ns})}$$

AN AIS-0 Relevant Results

After filtering, 3.2 keV peak appears in our background

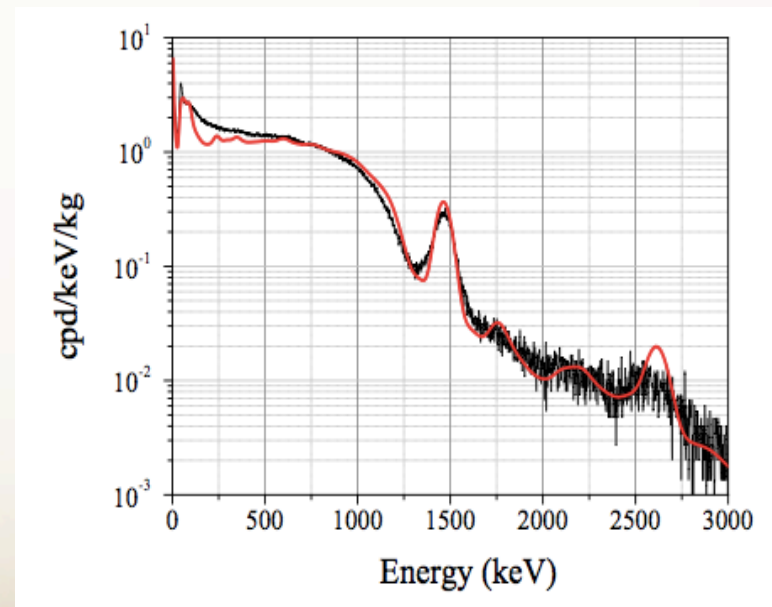
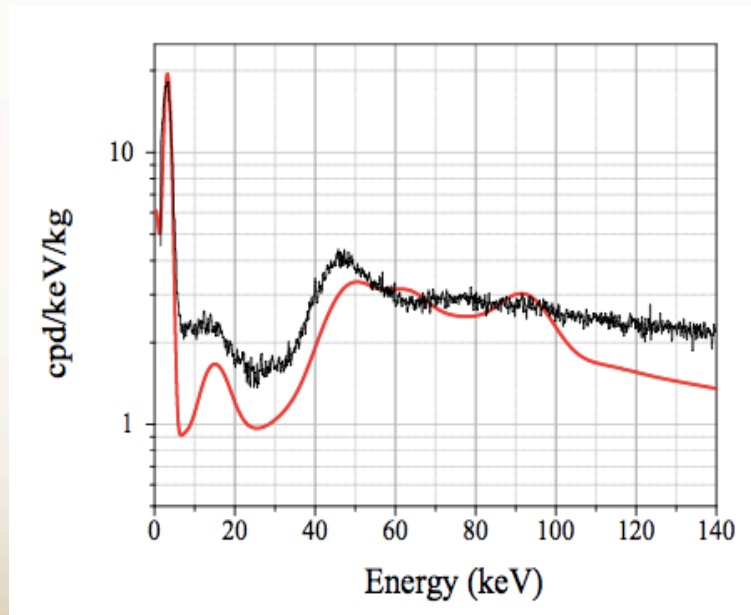
Too high ^{40}K level in ANAIS-0, but 2 keVee threshold can be confirmed



AN AIS-0: Background Model

We have built a background model for the ANAIS-0 module, based on radiopurity input data for the different detector and shielding components.

Simulations have been done using Geant-4



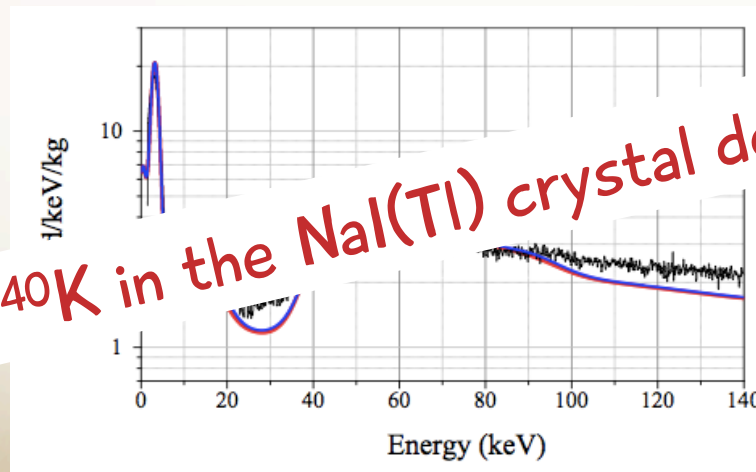
S. Cebrián et al., *Astroparticle Physics* 37 (2012) 60

ANAIS-0: Background Model

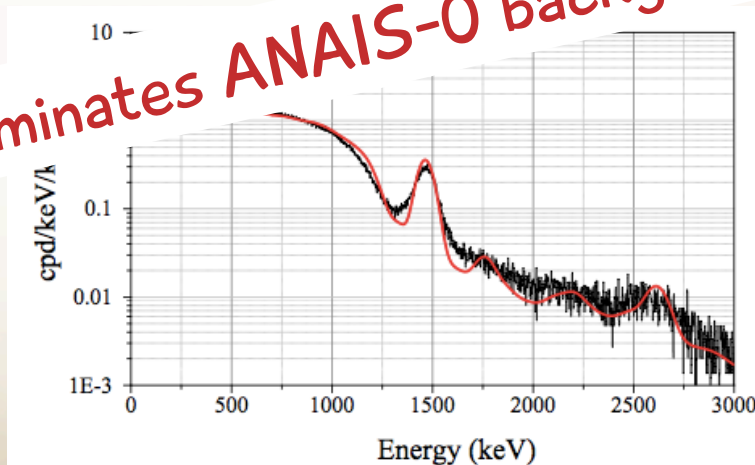
We have built a background model for the ANAIS-0 module, based on radiopurity input data for the different detector and shielding components.

Simulations have been done using Geant-4

With slight and motivated modifications to this model we achieve a remarkable agreement



40K in the NaI(Tl) crystal dominates ANAIS-0 background



S. Cebrián et al., Astroparticle Physics 37 (2012) 60

Searching for radiopure NaI powder

HPGe spectrometry screening at LSC of K content in NaI powder from different providers.

Goal: Potassium content @ 0.02 ppm (or below)

<i>NaI powder</i>	<i>AS NaI powder</i>	<i>LIMITS AT 95% C.L.</i>
<i>Merck – commercial</i>	<i>Potassium</i>	<i><0.09 ppm</i>
<i>Alfa-Aesar – commercial</i>	<i>Uranium-238</i>	<i><0.055 ppb</i>
	<i>Thorium-232</i>	<i><0.13 ppb</i>
<i>ESI – purified</i>	<i>0.32 ± 0.08</i>	
<i>AS – selected</i>	<i><0.09 (95% C.L.)</i>	



Only upper limits using HPGe spectrometry

Crystal Growing and Manufacturing

Two 12.5 kg cylindrical crystals were grown and encapsulated by AS with the best raw powder:

- cylindrical in shape 4.75" diameter x 11.75" length
- encapsulated in OFHC copper, with an aluminized Mylar window to allow low energy calibrations.

Protocols for low-background machining, selection of materials to be used, surface cleaning procedures, etc. were proposed by the UZ, discussed and agreed by AS



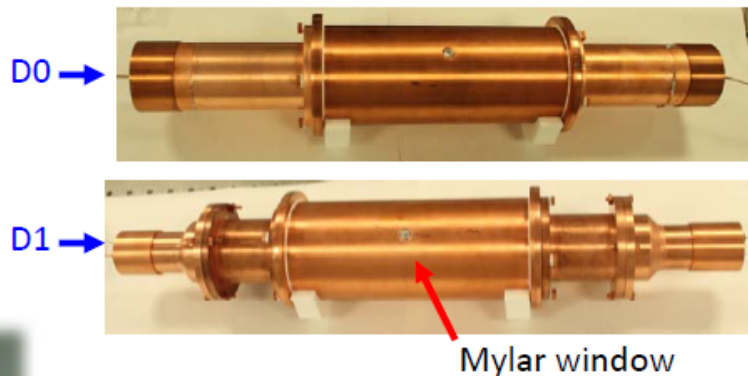
ANAIS-25 set-up

12.5 kg detectors made by AS
arrived to Spain at the end of
November 2012

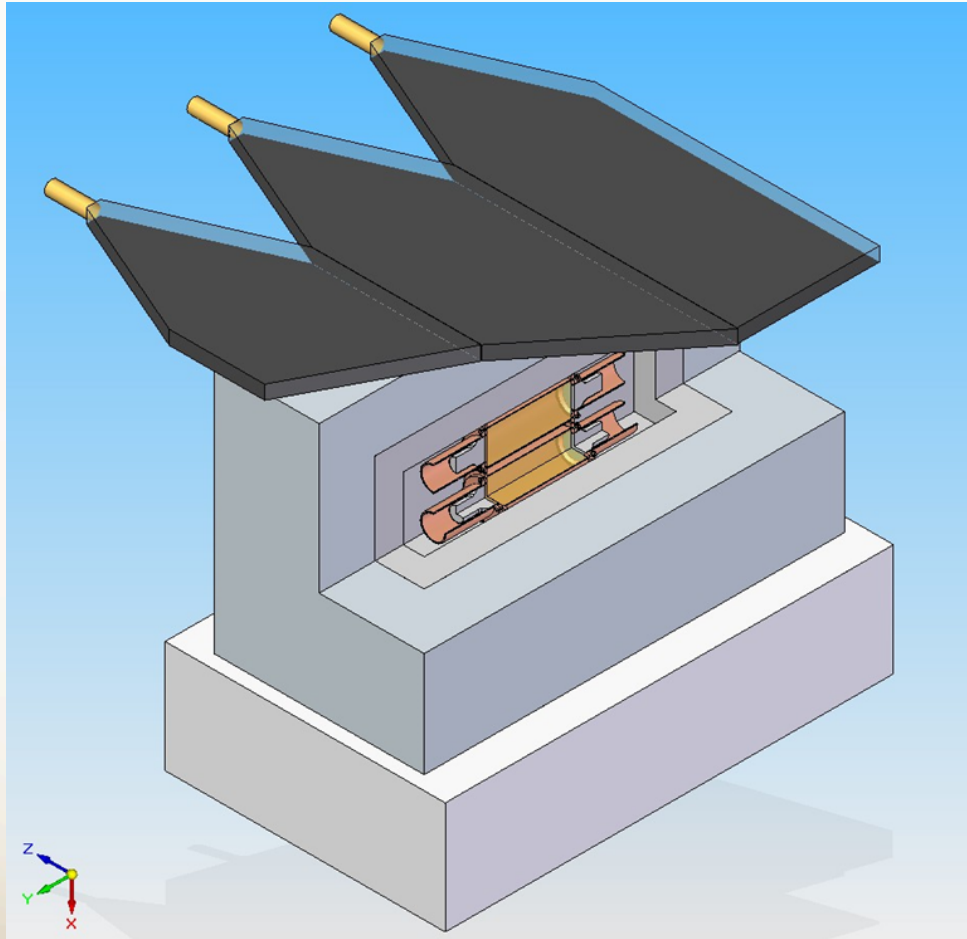
They were coupled to ULB and
VLB PMTs at LSC clean room

No light guides were used

Measurements started very fast



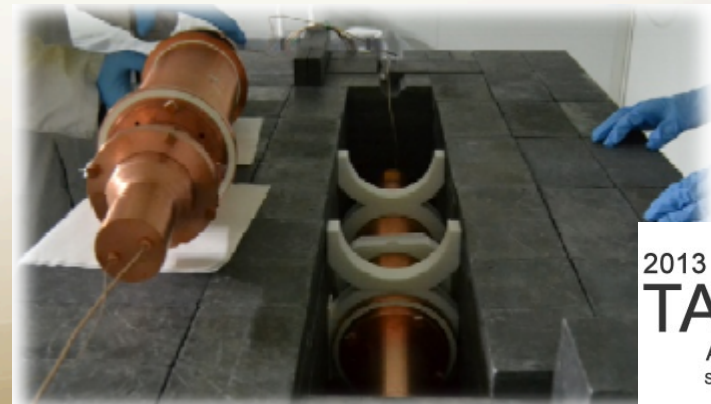
AN AIS-25 set-up



Taking data at LSC since
December 2012

Same shielding and readout
from ANAIS-0

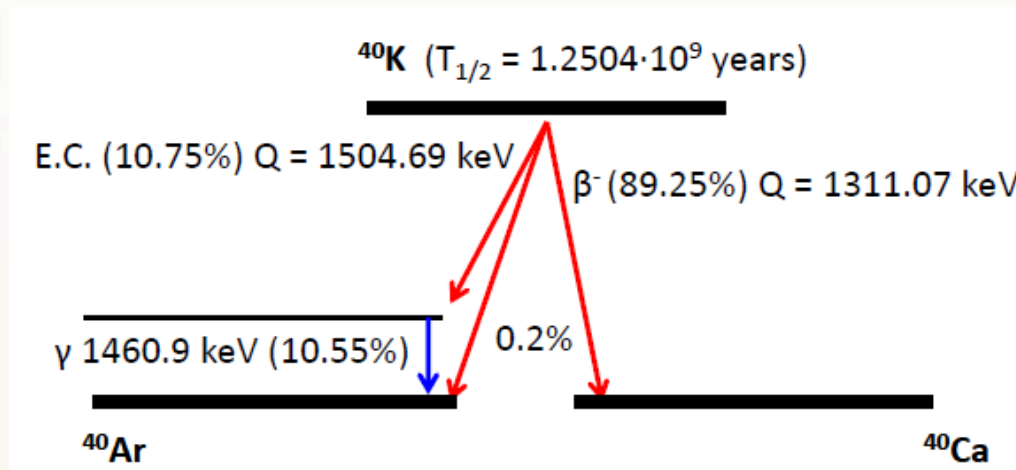
Main goals: determine
potassium content and general
performance assessment



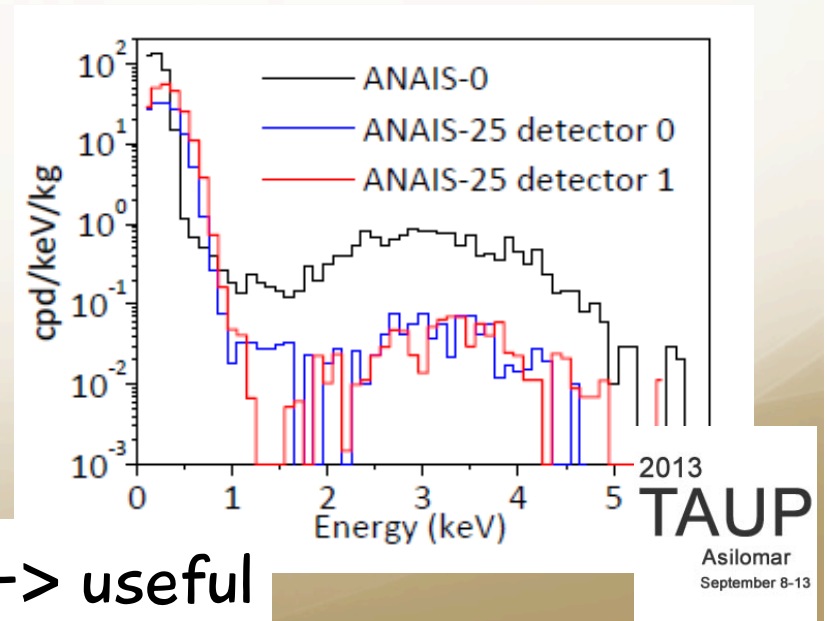
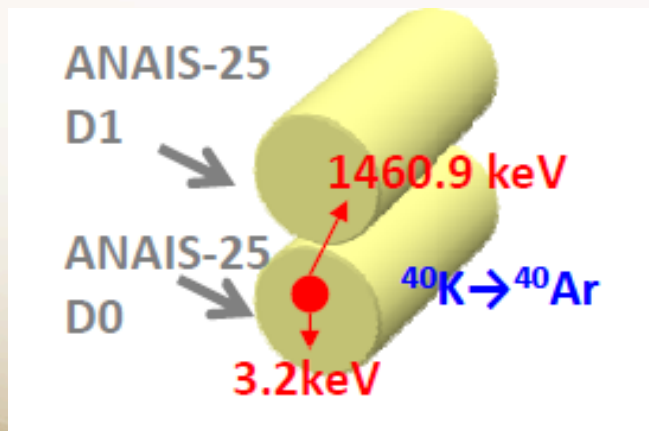
2013
TAUP
Asilomar
September 8-13

ANAIS-25: Potassium Content

Measured by coincidence



Result for ^{40}K bulk activity of the ANAIS-25 crystals:
 1.25 ± 0.11 mBq/kg
(i.e. 41.7 ± 3.7 ppb K)

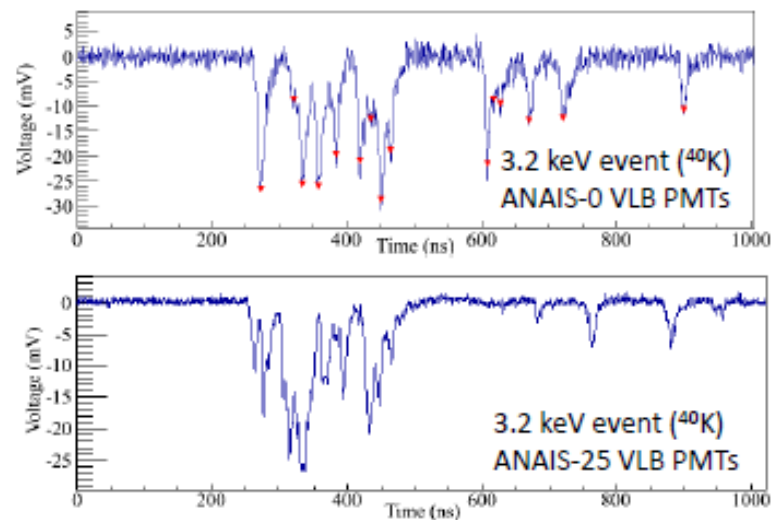


Very low energy TAGGED population \rightarrow useful

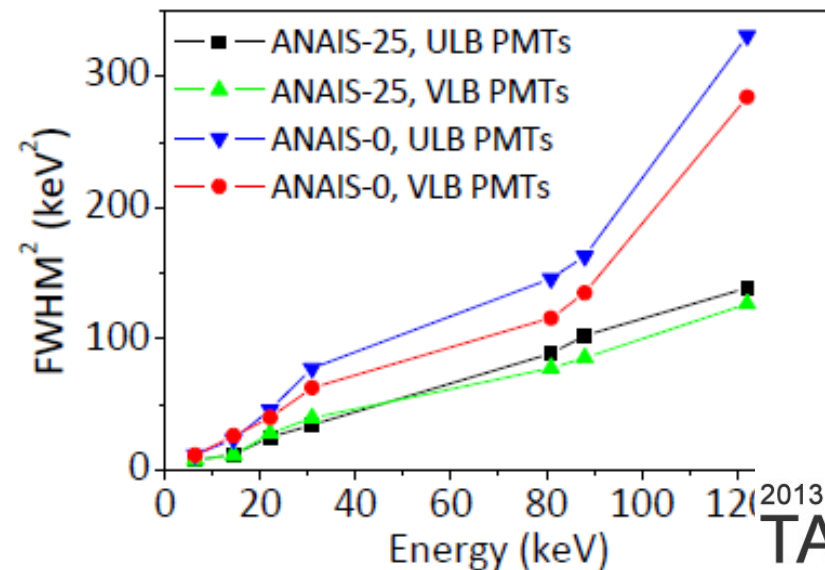
ANAIS-25: Light collection efficiency

Remarkable light collection efficiency

PMT model	ANAIS-0	ANAIS-25
	phe./keV	phe./keV
Ham. R12669SEL2	7.38 ± 0.07	16.13 ± 0.66
Ham. R11065SEL	5.34 ± 0.05	12.58 ± 0.13



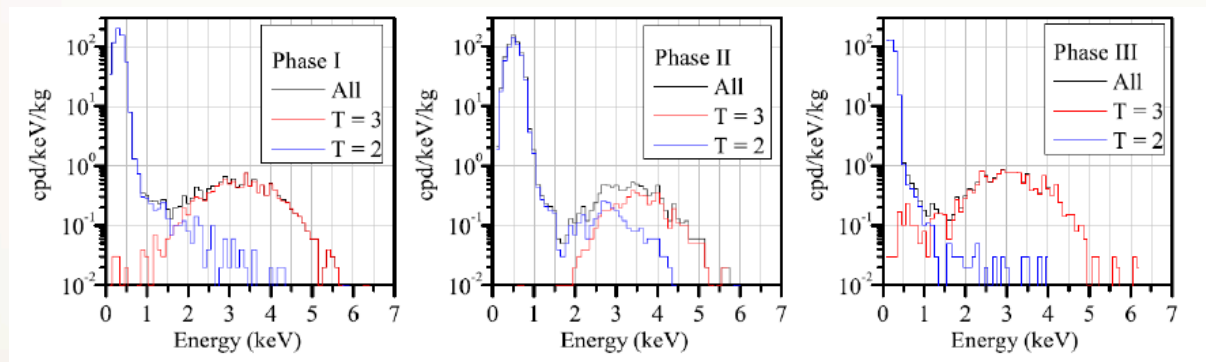
- Very good optical quality of the crystals
- No light guides used
- High quantum efficiency PMTs



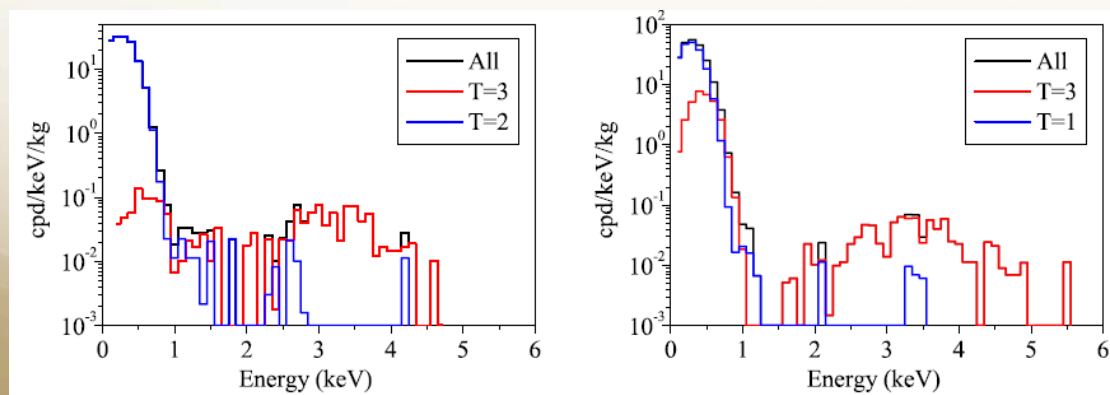
ANAIS-25: Trigger @ ph.e.

Trigger at ph.e. level is achieved

Trigger efficiency has been studied with the 3.2 keV peak selected by coincidence



ANAIS-0

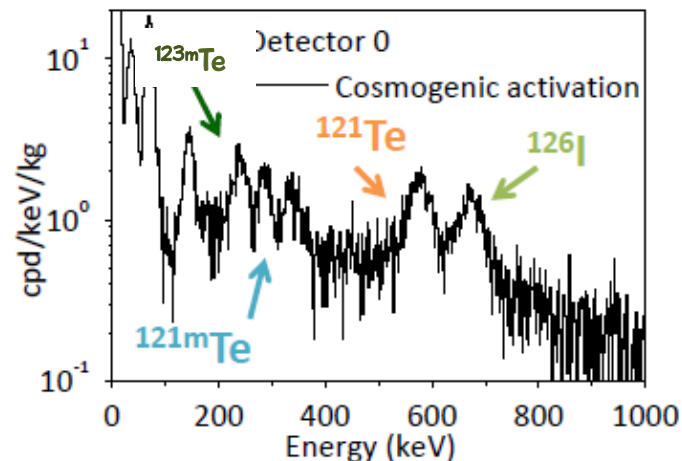
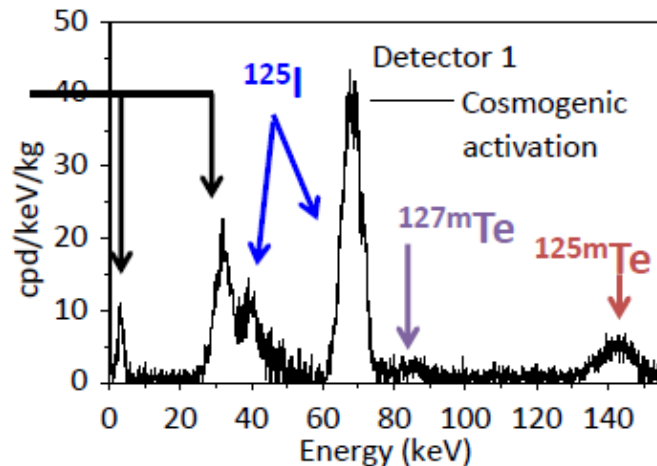


ANAIS-25

More than 97% of the events above 1.5 keV are triggering

ANAIS-25: Cosmogenic Activation

Emissions
from L, K
shell EC in
Te/I

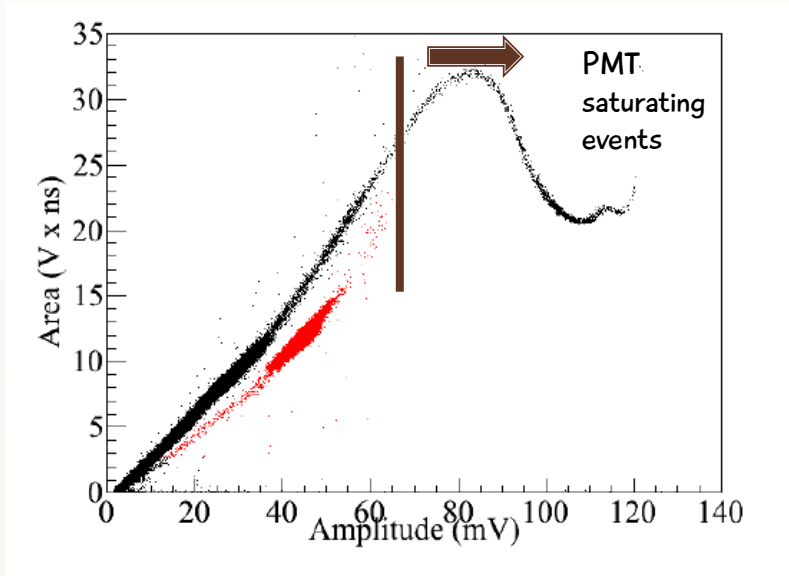


Main isotopes activated
cosmogenically identified in
ANAIS-25 data

Isotope	Lifetime	Decay	Main emissions
	days		keV
^{125}I	59.4	EC	35.5
^{126}I	13.11	EC, β^-	666.0
$^{121\text{m}}\text{Te}$	154	IT, EC	294.0
^{121}Te	16.8	EC	507.6, 573.1
$^{123\text{m}}\text{Te}$	119.7	IT	247.6
$^{125\text{m}}\text{Te}$	57.4	IT	144.8
$^{127\text{m}}\text{Te}$	109	IT, β^-	88.3

Contribution from Radon inside the shielding + isotopes
activated cosmogenically along 75 first day of data

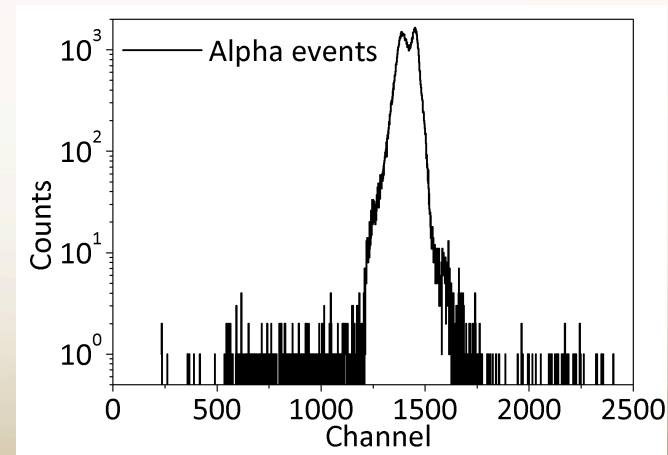
AN AIS-25: Alpha Events



Alpha particles are clearly distinguished from PSA

Very high alpha rate:
3,15 mBq/kg

Spectrum indicates natural chains out of equilibrium with a dominant contribution



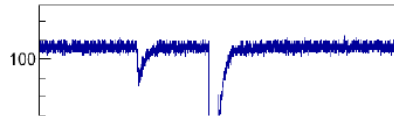
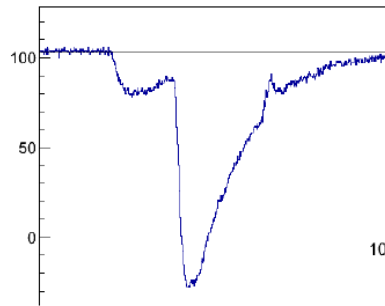
ANAIS-25: Alpha Events

Alpha particles are clearly distinguished from PSA

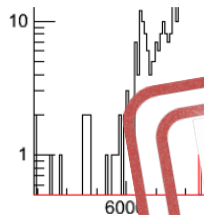
Very high alpha rate:
3,15 mBq/kg

We have searched for coincident events from ^{212}Bi -Po and ^{214}Bi -Po coincidences in a dedicated set-up

Above the main alpha peak



Isotope	Activity (mBq/kg)	
	ANAIS-0	ANAIS-25
^{40}K	12.7 ± 0.5	1.25 ± 0.11
$^{238}\text{U}/^{234}\text{U}$	0.075 ± 0.005	-
^{230}Th	0.023 ± 0.007	-
^{226}Ra	0.098 ± 0.004	0.010 ± 0.002
^{210}Pb	0.188 ± 0.005	~ 3.15
^{232}Th	0.013 ± 0.005	-
^{228}Th	0.035 ± 0.003	0.003 ± 0.001



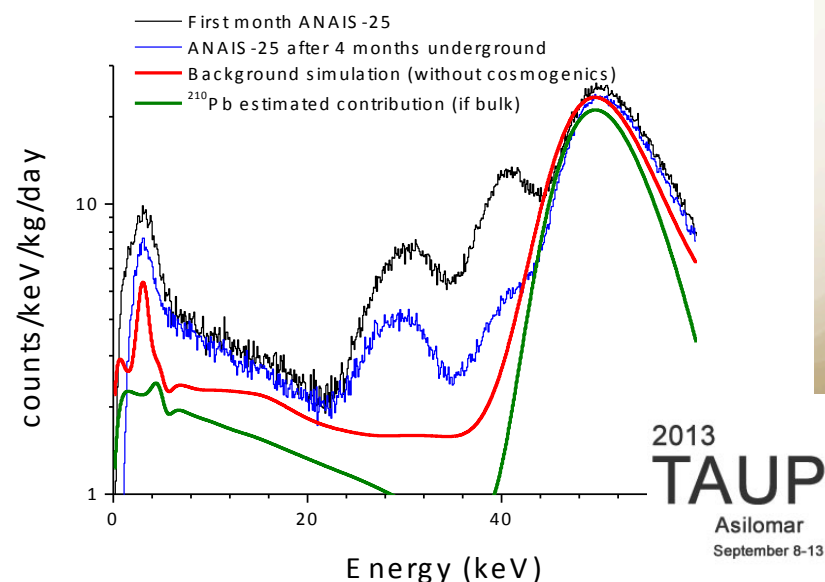
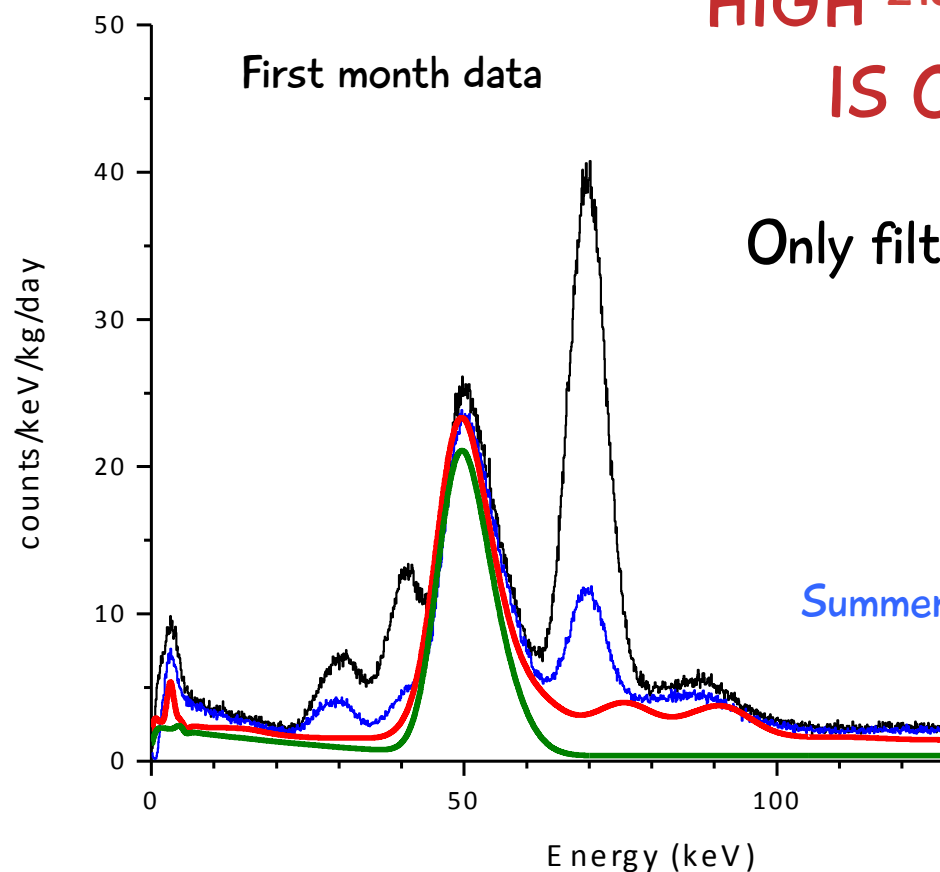
PRELIMINARY

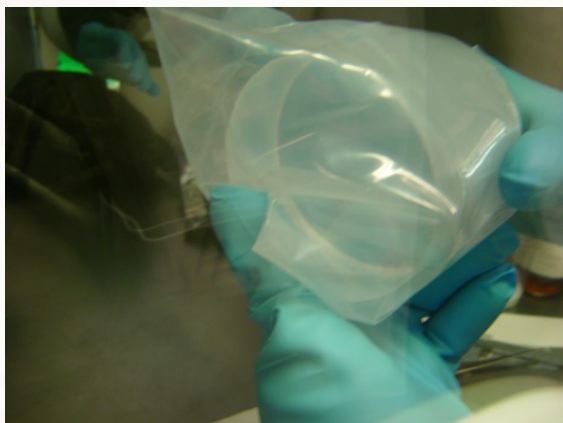
ANAIS-25: Background Model

Our background model (without cosmogenic isotopes) reproduces nicely most of the low energy background

HIGH ^{210}Pb CONTENT IN THE BULK
IS COMPATIBLE WITH LE DATA

Only filtered in $n > 5$ peaks in each PMT





AS 1k measurement

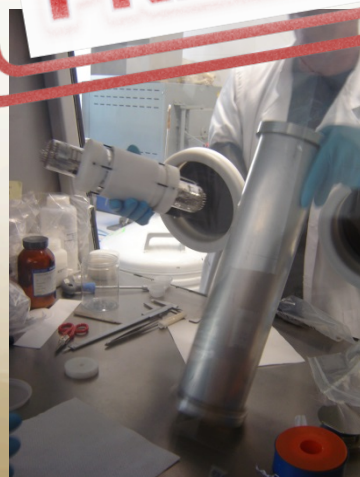
High alpha rate in ANAIS-25 modules



1 kg crystal from a new grown NaI(Tl) ingot @
AS – NUDE & mounted at the UZ
For measuring alpha rate
(August 2013)



PRELIMINAR



**Total Alpha Rate:
1.06 mBq/kg**



PMT Testing

HP Ge spectrometry at LSC



Ham LB



Ham ULB



Ham VLB



Model	^{40}K (mBq/PMT)	^{232}Th (mBq/PMT)	^{238}U (mBq/PMT)
HAM - R6233-100 HAM-LB	678 ± 42	68 ± 3	100 ± 3
HAM - R11065SEL HAM-ULB	12 ± 7	3.6 ± 1.2	$^{238}\text{U}: 47 \pm 28$ $^{226}\text{Ra}: 8.0 \pm 1.2$
HAM - R6956MOD HAM-VLB	97 ± 18	20 ± 2	$^{238}\text{U}: 128 \pm 38$ $^{226}\text{Ra}: 84 \pm 3$

PMT Testing



Ham ULB

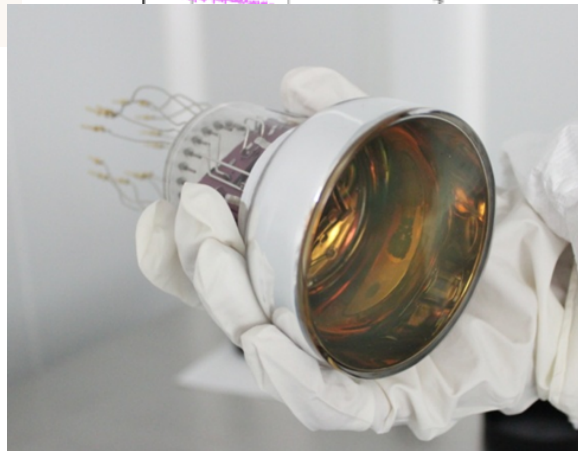


Ham VLB

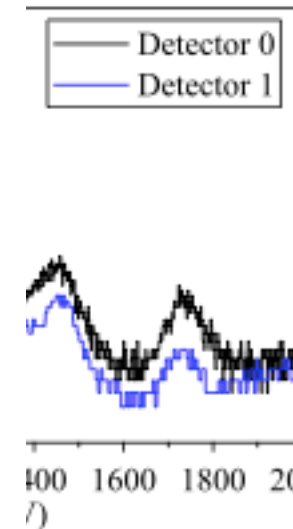
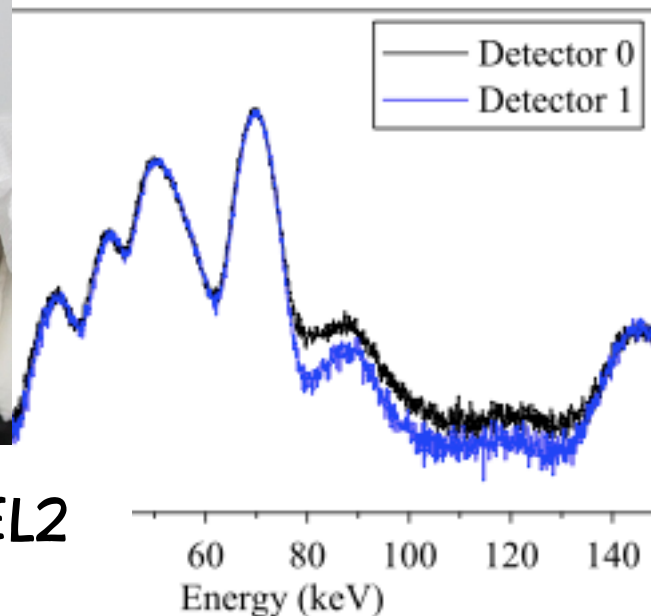
Direct Measurement in ANAIS-0 prototype

We would like to avoid LG: is PMT background so relevant?

Direct Measurement in ANAIS-25



42 units of R12669 SEL2 have been purchased

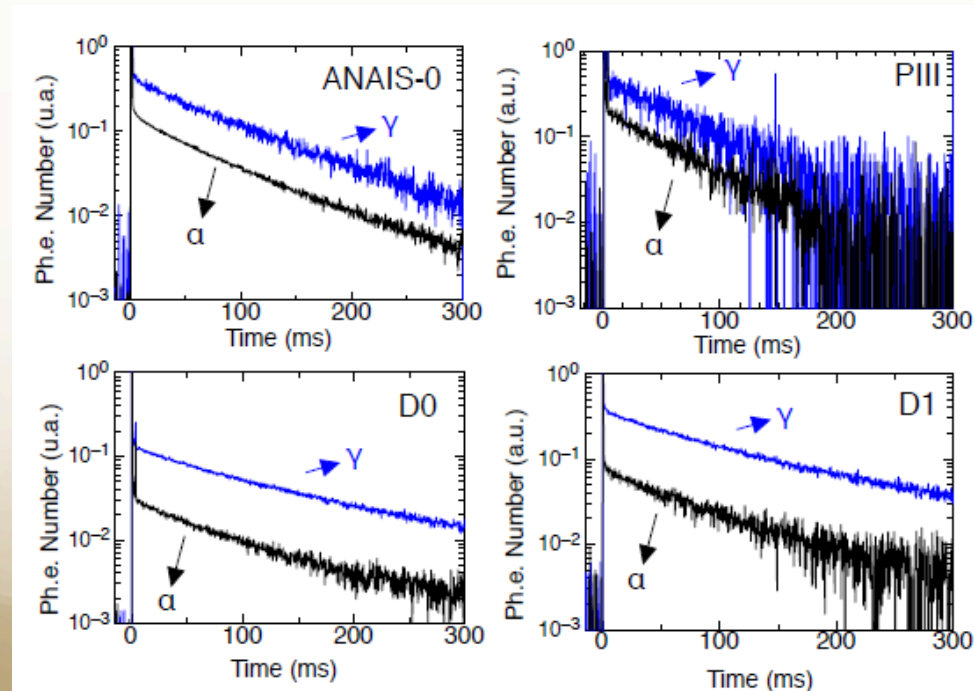


Slow Scintillation Constants in NaI(Tl)

To appear in Optical Materials

<http://arxiv.org/abs/1307.1398>

- Ph.e. have been identified individually after every high energy event and their time arrival saved in a 300 ms window
- Histograms are built separately for alpha and gamma events
- Four large crystals from different manufacturers have been studied



ANAIS-25

Slow Scintillation Constants in NaI(Tl)

To appear in Optical Materials

<http://arxiv.org/abs/1307.1398>

- Mean times in the range 75-90 ms are obtained for all the crystals studied
- Gamma/Muon events produce much more effectively this slow scintillation
- It is able to trigger in **AND** mode two PMTs in a dark matter search !!

Detector	$N_{\alpha}/N_{\gamma/\mu}$	$\tau_{\alpha,mean}$ (ms)	$\tau_{\gamma/\mu,mean}$ (ms)
AN AIS-0	0.4 ± 0.2	75.5	80.3
PIII	0.8 ± 0.2	68.3	69.0
D0	0.5 ± 0.1	92.1	101.7
D1	0.4 ± 0.1	88.3	99.5

AN AIS-25

2013
TAUP
Asilomar
September 8-13

Outlook

- NaI powder at 40ppb potassium level has been found -> further improvement should be possible, (see SABRE talk)
- NaI(Tl) detectors with outstanding light collection efficiency have been built by AS – UZ
- ^{210}Pb (probably from ^{222}Rn) is a problem: AS is improving their protocols and we look forward cleaner crystals -> AS 1k result is promising
- Electronics, acquisition software and analysis is reliable and has been thoroughly tested
- Good understanding of background at high and low energy

Prospects

- ANAIS-25 filtering procedure still developing
- ANAIS 250kg simulation will be ready soon – ^{40}K is rejected by coincidences between modules and large size of our crystals is also an advantage to prevent 1461 keV gamma from escaping
- Working with AS to get as soon as possible a new improved prototype – Progress and data are being shared with DM-ice collaboration
- Hopefully we could grow ANAIS crystals along 2014